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# How attractive are short-term CDM forestations in arid regions? The case of irrigated croplands in Uzbekistan

Utkur Djanibekov *, Asia Khamzina, Nodir Djanibekov, John P.A. Lamers

*Center for Development Research (ZEF), University of Bonn, Walter-Flex-Str. 3, 53113, Bonn, Germany*

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ABSTRACT

This study analyzed the financial attractiveness of Clean Development Mechanism Afforestation and Reforestation (CDM A/R) in irrigated agricultural settings. The Net Present Value (NPV) and Internal Rate of Return (IRR) of CDM A/R were estimated by analyzing the case of Khorezm region in Uzbekistan, where a mixed-species tree plantation was established on marginal cropland. The dual purposes of carbon sequestration and production of fruits, leaves as fodder, and fuelwood were studied over a seven-year rotation period. We compared the opportunity costs of land in marginal agricultural areas between this short-rotation plantation forestry and the annual cultivation of the major crops in the region, i.e., cotton, winter wheat, rice, and maize. The analyses were performed considering different levels of irrigation water availability, from 0 to 30,000 $m^3$/ha, to reflect the reality of a high variability of water supply in the region. The NPV of CDM A/R ranged between 724 and 5794 USD/ha over seven years, depending on the tree species. Among the latter, *Elaeagnus angustifolia* L. had the highest profits due to the annually recurring cash flows generated from fruit production. Temporary Certified Emission Reductions (tCER) ranged within 399–702 USD/ha after the assumed 7-year crediting period and would not suffice to cover initial investments and management costs of tree plantations. IRR peaked at 65% with *E. angustifolia* under the conventional afforestation and measured −10% and 61% when considering only the tCER and the CDM A/R, respectively. In contrast, other species had higher IRRs in case of the CDM A/R. The total profits from tree plantations exceeded those of both cotton and winter wheat, even with the assumption that there was an optimal irrigation supply for these crops. Rice production was overall the most profitable land use option but required water input of 26,500 $m^3$/ha/year, which is not consistently available for marginal croplands. We argue that the current global average price of 4.76 USD/tCER is insufficient to initiate forestry-based CDM projects but, in the absence of other incentives, can still motivate forestation of degraded croplands for land rehabilitation and the provisioning of non-timber products. Given the low irrigation needs of trees, 3–30% of the crop water demand, a conversion of degraded cropland to forested areas could save up to 15,300 $m^3$/ha/year at the current tCER price. Combining the monetary value of water and carbon would enlarge the scope for CDM A/R in irrigated drylands, thus enhancing the investments in marginal land rehabilitation and strengthening the resilience of rural populations to the repercussions of climate change.



## 1. Introduction

Over the last few decades, global warming has been recognized as a major environmental concern (IPCC, 2007). Reflections on options to mitigate the impact of climate change have suggested that storing carbon (C) in tree plantations is a cheaper solution than other offset schemes (Boyd et al., 2007). Tree plantations established on degraded croplands in drylands may be a land use option that sequesters C and improves degraded soils (Nosetto et al., 2006). Arid areas are mainly situated in North Africa and Central and West Asia, comprising nearly 34 million ha (Mha) of irrigated croplands, of which about 30% are exposed to land degradation (El Beltagy, 2002), resulting in economic losses. This concern is illustrated in the case of Uzbekistan, Central Asia, where almost a half of the arable land is saline and about 885,000 ha are marginal, i.e., generate low profits or no profits from annual crop cultivation (Ministry of Agriculture and Water Resources of Uzbekistan, 2010). Reportedly, Uzbekistan loses 31 million (mln) USD annually due to salinization and 12 mln USD due to the withdrawal of highly saline lands from agricultural production (World Bank, 2002).

Afforestation as an alternative use of degraded croplands in the irrigated areas of Uzbekistan can increase the productive capacity of the land via the provisioning of tree products for income generation (Khamzina et al., 2008; Lamers et al., 2008). For instance, the rural population has a high interest in fuelwood as a means to reduce their reliance on gas, which is presently the main source of energy. But this is not a guaranteed source due to interruptions in supplies or limited access to the central grid. The inclusion of protein-rich tree leaves into

* Corresponding author. Tel.: +49 228 731852; fax: +49 228 731869.
*E-mail address:* utkur@uni-bonn.de (U. Djanibekov).


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the feeding ration of dairy cows has the potential to both increase the nutritional feed value and reduce feed costs (Djumaeva et al., 2009). Ecosystem services from tree plantations include irrigation water saving (as trees mostly rely on groundwater), a considerable increase in soil nutrient stocks and an accumulation of C in soil and in woody biomass (e.g., Hbirkou et al., 2011; Khamzina et al., 2012). In theory, C sequestration through tree plantations on marginal croplands may offer farmers also benefits in the form of Certified Emission Reductions (CER = 1 ton of avoided $CO_2$ emissions) under the Clean Development Mechanism Afforestation and Reforestation (CDM A/R) of the Kyoto Protocol. Thus, setting appropriate incentives for establishing tree plantations in irrigated drylands contributes to improving the global $CO_2$ balance and the livelihoods of local residents.

The establishment of tree C projects on marginal agricultural lands has gained increasing attention from researchers, albeit with contrasting results. While some studies concluded that present policies have encouraged tree planting as a climate change mitigation option (e.g., Parks and Hardie, 1995; Niu and Duiker, 2006), others have claimed that such projects could be attained only at a significant cost and would require a substantial change in the present climate agenda regulations (e.g., van Kooten, 2000; Krcmar et al., 2005; Tal and Gordon, 2010). On-going debates in forestry studies have not conclusively resolved the concern over determining the price for C stored in wood. The C-wood price in voluntary and regulated markets ranged from 0.65 to more than 50 USD/t of $CO_2$ ($tCO_2$) (Hamilton et al., 2010). The price volatility may constrain land users' participation in CDM A/R; thus, further research needs to identify a CER price that would incentivize forestation on marginal croplands.

Furthermore, one of the main obstacles in growing trees for climate change mitigation is land tenure insecurity (Unruh, 2008), which is a factor also in Uzbekistan. Considering that the risk of losing lease contracts of farmland restrains Uzbek farmers from investing in long-term land-use activities (Djanibekov et al., 2010), a short-rotation forestry with renewable credits might be a more appropriate option to encourage farmers' participation in CDM A/R. Estimations of rotational timber harvesting and carbon sequestration in biomass were conducted within the context of temporary CER (tCER) of CDM and showed that these mechanisms were cost-efficient to combat global warming (Galinato and Uchida, 2010; Guitart and Rodriguez, 2010; Olschewski and Benítez, 2010). The tCER option addresses the issue of hedging one's bets against the risks and provides financial benefits in the short term (Maréchal and Hecq, 2006). Moreover, several researches pointed at substantial benefits when substituting fuelwood derived from short-term rotation tree plantations for fossil fuels, as opposed to sequestering C in tree biomass (Baral and Guha, 2004; Kaul et al., 2010; Miah et al., 2011). However, there is a lack of assessments of CDM A/R with the joint benefits of non-timber production and C sequestration.

Consideration of land attributes in climate change mitigation via tree plantation projects is an important factor that influences the C sequestration patterns. Studies by Olschewski et al. (2005) and Benítez and Obersteiner (2006) estimated the C price of tree plantation projects in association with the land quality. To our knowledge, there have been no studies that have related the C price to the environmental value associated with improving degraded soils and saving irrigation water, both of which are factors of high importance for irrigated drylands.

Considering these gaps, the objective of this paper was twofold: (i) to investigate the financial attractiveness of a short-term CDM A/R option on a marginal irrigated cropland using empirical data on multi-species tree plantations from the Khorezm region in Uzbekistan and (ii) to determine the tCER prices at which short-rotation forestry becomes profitable under various levels of irrigation water availability to the marginal cropland. The Net Present Value (NPV) and Internal Rate of Return (IRR) of the CDM A/R included multiple tree products, i.e. tCER, fruits, leaves as fodder, and fuelwood for an assumed seven-year project period. The opportunity costs of adopting the CDM A/R were calculated through the gross margins of the dominant annual crops cultivated on marginal lands. Determining tCER prices at which short-rotation forestry becomes beneficial would encourage CDM forestations that provide broader environmental benefits by increasing water use efficiency and combating land degradation, thus contributing to the sustainable development in arid areas.

## 2. Methodology

### 2.1. Case study region

The Khorezm region (Fig. 1) lies between 60°05′ and 61°39′ E longitude and 41°13′ and 42°02′ N latitude, in northwest Uzbekistan. Annual precipitation is approximately 100 mm which is by far exceeded by the annual evapotranspiration (1400–1600 mm) (Glazirin et al., 1999). The precipitation largely occurs during the fall–winter months thus outside the crop growing season. The region comprises 680,000 ha, of which a 270,000 ha portion is cropland that entirely depends on irrigation. Nearly 1.7 million people reside in Khorezm, with 70% residing in rural areas. Agriculture accounts for 35% of the regional GDP (State Statistical Committee of Uzbekistan, 2010). In 2010, about 6030 private farms used 87% of the total arable land under non-transferable, usufruct rights based on land lease contracts signed for up to 50 years (Djanibekov et al., 2010). Approximately 50% and 20% of the arable land is cultivated annually with cotton and winter wheat, respectively. Both crops are part of the national development strategy and are cultivated according to the state's procurement targets. Cotton has been produced in Uzbekistan as a means of gaining export earnings whereas wheat has been introduced after the break-up of the Soviet Union to allow for national wheat self-sufficiency (Pomfret, 2008). A centerpiece of the procurement policy is farmers' fulfillment of the state-set production targets (Pomfret, 2008).

Given its downstream location along the Amu Darya River, Khorezm is one of the final recipients of the river's water supply that has diminished and has become unstable due to an increase in upstream utilization (Djalalov et al., 2005). Moreover, the amount of river water is predicted to reduce further due to the impacts of climate change (Perelet, 2007). Khorezm is susceptible to short- and long-term droughts, which during the years 2000, 2001, and 2008 resulted in major crop failures. The naturally poor drainage conditions coupled with irrigation inputs and insufficiently maintained drainage systems resulted in elevated groundwater tables and, thus, soil salinization (Tischbein et al., 2012). The combined area of cotton, wheat, rice, and maize within the low productive croplands amounts to about 25,000 ha (State Land Cadastre of Uzbekistan, 2010).

### 2.2. Description of afforestation site and biomass and C stock measurements

The experiment that provided data on tree growth on marginal cropland has been conducted since 2003 and is described in detail by Khamzina et al. (2008; 2009a). The information on tree production during 2003–2009 included in these analyses is presented in Table A (Appendix). In March 2003, tree plantation was installed on a marginalized cropping site of 2 ha. *Elaeagnus angustifolia* L., *Populus euphratica* Oliv. and *Ulmus pumila* L. species were planted in 36 pure-species plots of 105 $m^2$ (12 plots per species), completely randomized. At the time of planting, the one-year-old saplings were spaced 1.75 m between the rows and at 1 m within the rows, giving a stand density of 5714 trees/ha. The tree plots were initially irrigated at rates of 800 and 1600 $m^3$/ha/year. From 2005 onwards, irrigation was stopped and the trees relied entirely on groundwater. The impact of the irrigation treatment did not last beyond the plantation establishment phase and was only significant for *P. euphratica* (Khamzina et al., 2008). One to eight trees per plot were harvested and excavated at the end of the

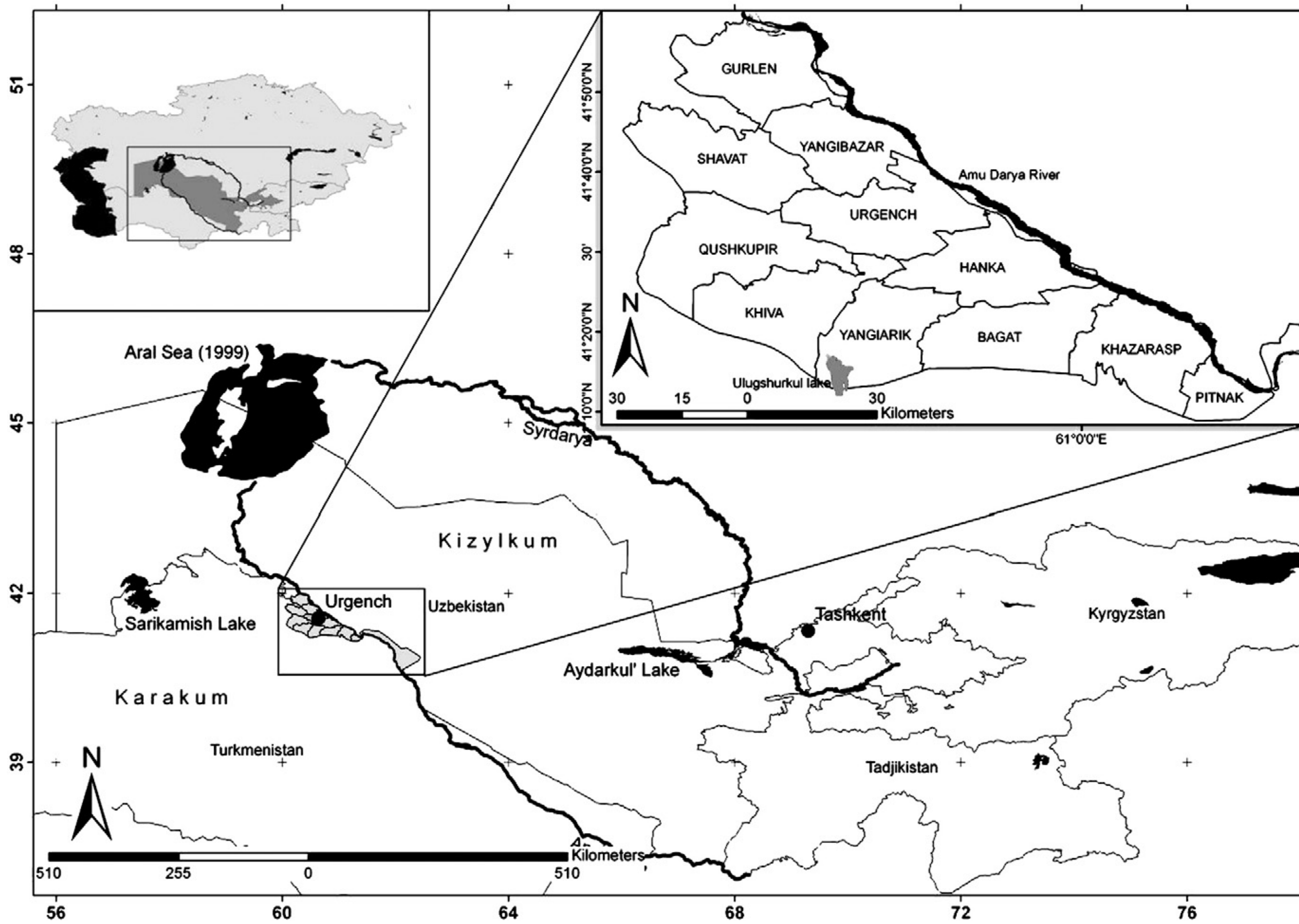


**Fig. 1.** Khorezm region in Uzbekistan.

growing season during the fall of each year between 2003 and 2009. The dry matter was measured according to tree bio-fractions, i.e., fruits, foliage, stem, twigs, and coarse roots.

The concentration of total C (%) in each woody fraction was annually analyzed after finely grounded samples were combusted in an elemental analyzer. The measured C concentration in stems, twigs and coarse roots ranged within 44–47%. The C stocks in plantations (t/ha) were estimated based on the wood biomass and the stand density. The results were converted into $CO_2$ equivalents by applying a factor of 3.67, accounting for the atomic weights.

### 2.3. Surveys and valuation of non-market tree products

The costs incurred during the first two years following afforestation were previously reported by Lamers et al. (2008). These expenses included the purchase of saplings, labor for site preparation, planting and maintenance costs. The latter incurred during the growing seasons in 2003–2004 and included labor-intensive, furrow irrigation fortnightly and manual weeding performed three times a year. Annual land taxes and labor costs for the subsequent years were based on the survey results.

Between July and October 2010, 80 private farm managers were randomly selected from all administrative districts of the Khorezm region and interviewed on the subject of crop yields, input and output prices, labor and fertilizer requirements, crop management, as well as consumption of tree products in the households. As the result of the surveys, farm-level data were collected. The interviewed managers were not able to provide details on each field and crop given that their farms had an average size of 60 ha and comprised up to 20 crop fields, distributed among several contracted families. For the same reason, although it was possible to collect information on overall input usage, such information could not be extracted specifically for marginal croplands.

Based on the farm survey results, the labor costs related to harvesting of fruits, leaves, and fuelwood were adjusted according to the wages that farmers paid to their workers, including payments in-kind and sharecropping arrangements, with respect to the type of provided services. The information on the crops' inputs use and prices is summarized in Table B (Appendix).

Prices of fuelwood and fodder were collected from the regional commodity markets. The average price of fuelwood in the local rural market was 40.9 USD/t for *E. angustifolia*, 38.7 USD/t for *P. euphratica* and 45 USD/t for *U. pumila*. In Khorezm, due to a lack of pastures, livestock feeding is based mainly on nutrient-rich but expensive crop by-products. Tree foliage is not marketed, therefore, as suggested by Lamers et al. (2008), the prices of the leaves of the selected tree species were calculated based on the foliar crude protein content compared to that of marketed dry alfalfa hay. The derived price was 53.3 USD/t for *E. angustifolia*, 32.7 USD/t for *P. euphratica* and 38.8 USD/t for *U. pumila* leaves. Timber production and price were not considered because the trees did not develop a sufficient stem size over the seven years since planting.

### 2.4. Crop water response on marginal croplands

Volumetric information on irrigation water use could not be collected through the farm surveys, as the water usage at the field and farm levels has not been accounted for by farmers. Therefore, the yield response of the selected crops to irrigation was established using the official recommendations on crop irrigation in Khorezm (Ministry of

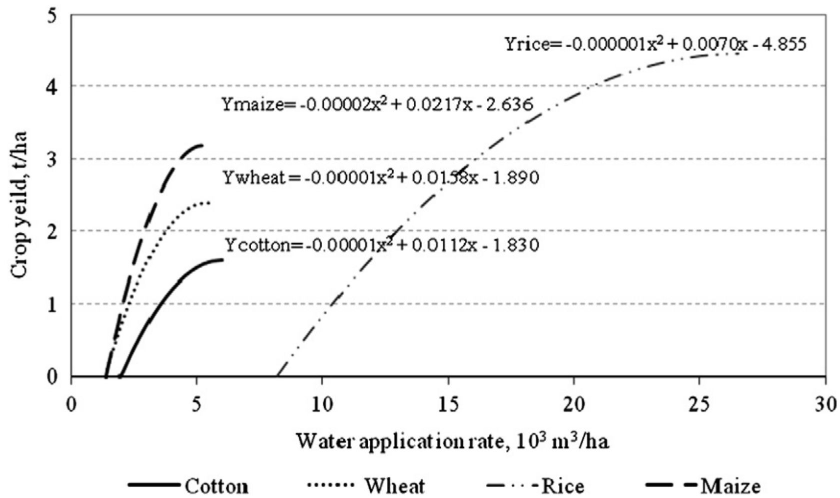


**Fig. 2.** Estimated yield response to irrigation of four crops on marginal lands.

Agriculture and Water Resources of Uzbekistan, 2001). Based on the data provided for crop yields under a range of watering rates, quadratic water-response functions were parameterized (Fig. 2). The maximum achievable crop yields were weighted based on the maximum yields for cotton, wheat, rice, and maize on marginal croplands in Khorezm (State Committee of Land Resources of Uzbekistan, 2002). Marginal croplands were defined according to the local classification of land productivity called *bonitet* that, using a 100-point scale, ascribes areas with *bonitet* levels below 41 to be low-productive (State Committee of Land Resources of Uzbekistan, 2002).

Under the assumption that farmers are profit-maximizers, the economical optimal irrigation rates were determined for cotton, wheat, and maize on low-productive croplands, which amounted to 6000, 5380 and 5300 $m^3$/ha/year, respectively. Rice, the most water consuming crop in Khorezm, would achieve its maximum yield on marginal croplands (4.45 t/ha) with 26,500 $m^3$/ha/year.

### 2.5. CER accounting

In forestry projects, emission reductions are reversible due to the non-permanent nature of trees. To address this non-permanence aspect, the CDM has defined temporary and long-term CER (tCER and lCER) that must be replaced by a specific time in the future. Short-term credits (tCER) are valid for one commitment period of five years, which means that credits for existing carbon stocks are re-issued after each verification event (Neeff and Henders, 2007). The crediting period for a proposed afforestation or reforestation project activity under the CDM is either a maximum of 30 years with no possibility of an extension or a maximum of 20 years which may be renewed up to two times. In our estimates of tCER, the 7-year project length was assumed given the availability of forestry data. The short-term project duration can be justified by the land tenure insecurity that prevents long-term investments in forestry land use (Djanibekov et al., 2010). We further assume that agreements on the crediting period can be negotiated between buyers and sellers.

To obtain tCER, certain eligibility criteria have to be met. The 'additionality' requirement, for instance, implies that more C should be sequestered in comparison to the baseline scenario of C levels in marginal croplands without forestation.[1] We assumed a constant C stock in the cropland because the entire above-ground crop biomass is harvested annually. Due to the complexity in accounting of C accrual in agricultural soils, only C that was sequestered in stem, twigs and coarse roots of the three tree species were considered for estimating tCER. The estimates could have been higher by including soil carbon, as dryland tree plantations sequester more C in soil than annual crops do (Scheer et al., 2008; Hbirkou et al., 2011).

Our study considered the option of a small-scale CDM A/R, which is less costly than large-scale projects with transaction costs of 360,000–610,000 USD (Michaelowa and Stronzik, 2002; UNEP, 2007). To reduce the costs and encourage small-holder farmers' participation, simplified modalities and procedures were adopted for the small-scale CDM A/R, which were defined as those annually sequestering less than 16,000 $tCO_2$ (UNFCCC, 2007). Since CDM A/R projects have not yet been implemented in Uzbekistan, we assumed transaction costs of 105,000 USD, as estimated by Schlamadinger et al. (2007). Next, CDM transaction costs per hectare were identified by taking into consideration the land area that would sequester 16,000 $tCO_2$ based on the uptake potential of the tree species under study. The choice of the maximally allowed project size (16,000 $tCO_2$) is based on the need to estimate the maximal land area that would have been required for initiating a small-scale project in the land-scarce agricultural region. The $CO_2$ uptake rate was estimated as an average annual uptake observed in tree plantations over the seven year period since planting.

To estimate the benefits of CDM A/R on marginal croplands we calculated the NPV of each land use activity i.e., the annual crop cultivation, conventional afforestation, sole tCER payments, and CDM A/R, as follows:

$$\mathrm{NPV}^A = \sum_{t=1}^{T} \frac{P_t^A Y_t^A - C_t^A}{(1+r)^t} \tag{1}$$

$$\mathrm{NPV}^F = \sum_{t=0}^{T} \frac{P_t^F Y_t^F - C_t^F}{(1+r)^t} \quad \text{and} \quad C_t^F = L_t + E_t + M_t + H_t \tag{2}$$

$$\mathrm{NPV}^{\mathrm{TCER}} = \sum_{t=0}^{T} \frac{P_t^{\mathrm{TCER}} Y_t^{\mathrm{TCER}} - C_t^{\mathrm{TCER}}}{(1+r)^t} \quad \text{and} \quad C_t^{\mathrm{TCER}} = L_t + E_t + M_t + S_t \tag{3}$$

$$\mathrm{NPV}^{\mathrm{CDM}} = \sum_{t=0}^{T} \frac{P_t^{\mathrm{TCER}} Y_t^{\mathrm{TCER}} + P_t^F Y_t^F - C_t^{\mathrm{CDM}}}{(1+r)^t} \quad \text{and} \quad C_t^{\mathrm{CDM}} = L_t + E_t + M_t + H_t + S_t \tag{4}$$

where superscript *A* stands for crop cultivation, *F* for conventional afforestation, *TCER* for tree plantation aiming solely at tCER, and *CDM* for

[1] More information on this program can be found at http://cdm.unfccc.int/Reference/Guidclarif/index.html

CDM A/R. Subscript $t$ stands for the analyzed (0, 1, 2, …, $T$) years with $T$ being equal to 7 years.

NPV Net Present Value of all revenues and costs related to any land use activity [USD/ha].

$P$ price of crops, crop by-products, tree products (fruits, leaves, and fuelwood), and tCER [USD/t].

$Y$ yield of crops, crop by-products, tree products (fruits, leaves, and fuelwood), and carbon sequestered in tree biomass (in stem, twigs, and roots) [t/ha].

$C$ all costs related to an activity, such as costs of crop cultivation, costs of annual land tax and two-year payments for irrigating the tree plantation ($L$), establishing the tree plantation (including saplings, machinery use, labor use for field preparation and planting) ($E$), maintaining the tree plantation ($M$), harvesting and transportation costs of tree products (fruits, leaves, and fuelwood) ($H$), as well as transaction costs of the small-scale CDM A/R ($S$) (project design, registration, verification, and monitoring) [USD/ha]. We assumed that farmers use conventional technologies for annual crop cultivation on marginal croplands. Therefore, in our calculations there are no investments in crop cultivation in $t=0$. In addition, labor and machinery costs varied with respect to crop yields, while the value of land taxes, water user payments, fertilizer and transportation costs was fixed.

$r$ estimated real interest rate which represents the difference between the observed nominal interest rate (22%) and a consumer price index (ca. 8%; ADB, 2011) in Uzbekistan in 2009. Consequently, in this study, $r$ is equal to 14%.

Additionally, the Internal Rate of Return (IRR), that offers a possibility to analyze the returns to investments without choosing arbitrarily a discount rate, was calculated for the conventional afforestation, solely tCER, and CDM A/R. The solution is obtained by computing a new discount rate for which $NPV^F$, $NPV^{TCER}$, and $NPV^{CDM}$ in Eqs. (2)–(4) should be equal to zero. According to the IRR, an investment would be financially rational if the computed discount rate is greater than the real interest rate (in our study 14%), although the IRR does not reveal any information about the volume of the finances involved.

A land use change toward CDM A/R is worthwhile when $NPV^{CDM}$ is greater than the NPV from crop production ($NPV^A$).

$$NPV^{CDM} = \sum_{t=0}^{T} \frac{P_T^F Y_T^F - C_t^F}{(1+r)^t} + \sum_{t=0}^{T} \frac{P_t^{TCER} Y_t^{TCER} - S_t}{(1+r)^t} \geq NPV^A \tag{5}$$

Using Eq. (2), Eq. (5) can be modified as following:

$$NPV^{CDM} = NPV^F + \sum_{t=0}^{T} \frac{P_t^{TCER} Y_t^{TCER} - S_t}{(1+r)^t} \geq NPV^A. \tag{6}$$

According to Eq. (6), the total NPV of the conventional afforestation and the revenues from tCER less the transaction costs should be greater than the NPV of crop production.

### 2.6. TCER in irrigated areas

In the arid climate, the availability of irrigation water determines farmers' decisions on crop cultivation in addition to the need of fulfilling the crop production targets set by the state. Given the low irrigation demand of tree plantations observed (Khamzina et al., 2009a) in contrast to crop water demand, the CDM A/R can be viewed as an incentive for increasing water use efficiency, leading to irrigation water savings. Water availability can be spatially heterogeneous because croplands located near a water source (e.g., main irrigation canal or a river) are better endowed with irrigation water, whereas tail-end areas further away from water sources may have less stable water supplies. This variability results in different economic values from crop cultivation for different locations. Assuming that $P_t^{TCER}$ does not change over the 7-year period examined ($t$), the minimum level of $P^{TCER}$ that would motivate the farmer's decision to shift from annual cropping to CDM A/R can be calculated from Eq. (6) as follows:

$$P^{TCER} = \frac{NPV^A - NPV^F}{\sum_{t=0}^{T} Y_t^{TCER}(1+r)^{-t}} + \frac{\sum_{t=0}^{T} S_t(1+r)^{-t}}{\sum_{t=0}^{T} Y_t^{TCER}(1+r)^{-t}}. \tag{7}$$

Eq. (7) shows that the value of $P^{TCER}$ depends on the level of irrigation water availability for marginal croplands. This is reflected in crop yields ($Y^A$) in $NPV^A$ that are calculated as quadratic water-response functions as discussed in Section 2.4 (Fig. 2). According to Eq. (7), higher prices of tCER would lead to reduced irrigation inputs because areas devoted to crops that require a great deal of water (e.g. rice) would be reduced in favor of tree plantations. Assuming different values of $P^{TCER}$, the water saving potential of a CDM A/R could be estimated as the difference between economic optimum rates of crop irrigation and those of tree irrigation.

Furthermore, according to Eq. (7) the value of $P^{TCER}$ would increase with increasing differences between $NPV^A$ and $NPV^F$ and decrease with increasing carbon sequestration potential ($Y^{TCER}$). Olschewski and Benítez (2005) showed that afforestation could become attractive without any carbon payments if $NPV^F$ was greater than $NPV^A$. However, according to Eq. (7) this condition does not hold since transaction costs ($S$) are not part of conventional afforestation but should be taken into account when estimating the price of tCER. Consequently, in our case, $P^{TCER}$ would increase with increasing transaction costs of establishing a small-scale CDM A/R ($S$).

## 3. Results

### 3.1. Gross margin of crops on marginal croplands

The most profitable crops in low productive lands in Khorezm were rice and maize, with respective gross margins of 1952 USD/ha and 420 USD/ha, when assuming for an optimal water supply (Table 1). In contrast, the cultivation of cotton and wheat on marginal croplands brought annual losses of 77 USD/ha and 17 USD/ha, respectively. Despite these losses, the two crops are strategically vital in Uzbekistan and are therefore still cultivated on approximately 50% of the marginal croplands in the study region. The private farm losses were mainly caused by the low procurement prices. For instance in 2009, half of the wheat yield was procured by the state at the price of 0.11 USD/kg, which was three times lower than the local market price. If wheat prices paid to farmers were adjusted to the local market levels, wheat cultivation on marginal croplands would become profitable, given the high levels of subsidies for inputs such as fertilizers, fuel, and for the use of machinery in Uzbekistan (Djanibekov, 2008).

### 3.2. Cost and benefits of CDM A/R

Investments in tree plantations predominantly occurred at the launch of the CDM A/R project and when tree harvesting took place. The cost structure of the CDM A/R revealed that initial CDM transaction costs (preparation of project design document, registration, and validation) amounted to 122–214 USD/ha depending on tree species, and the plantation establishment costs amounted to 637–793 USD/ha. These two components constituted the highest costs. The costs related to monitoring and verification of the CDM project at year seven were insignificant.

Considering the highest $CO_2$ sequestration rate of 16,000 $tCO_2$/year permitted for the small-scale CDM A/R option, the land area

**Table 1**
Annual gross margin of crops on marginal croplands.

| Parameters/crops | Units | Cotton | Wheat | Rice | Maize |
|---|---|---|---|---|---|
| Irrigation water requirements | $10^3$ $m^3$/ha | 5.98 | 5.38 | 26.59 | 5.3 |
| Crop yield | t/ha | 1.6 | 2.4 | 4.45 | 3.2 |
| Crop by-product yield | t/ha | 1.6 | 2.4 | 4.45 | 4.8 |
| Crop market price | USD/t | n.e. | 227.3[a] | 681.8 | 227.3 |
| Crop procurement price | USD/t | 227.3[b] | 107.7[b] | n.e. | n.e. |
| Crop by-product price | USD/t | 32.4 | 30.4 | 30.1 | 27.4 |
| Crop revenues | USD/ha | 415 | 475 | 3168 | 858 |
| Seed costs | USD/ha | 16 | 50 | 82 | 80 |
| Labor costs | USD/ha | 152 | 105 | 127 | 81 |
| Fertilizer costs | USD/ha | 152 | 135 | 166 | 150 |
| Machinery costs | USD/ha | 122 | 105 | 650 | 100 |
| Other costs[c] | USD/ha | 50 | 97 | 192 | 27 |
| Total variable costs | USD/ha | 492 | 492 | 1217 | 438 |
| Gross margins (+ profits/− losses) | USD/ha | −77 | −17 | 1952 | 420 |

n.e. = not eligible: selling cotton in rural market; state procurement target production for rice and maize.
[a] Farmers can sell half of harvested wheat grains at the market price.
[b] All harvested raw cotton and half of harvested wheat grains are purchased by the state.
[c] Costs related to transportation and payments for accessing rural markets.

required for afforestation would be 476 ha for *E. angustifolia*, 303 ha for *P. euphratica* and 533 ha for *U. pumila*. The farmer in Khorezm had on average 60 ha of cropland, of which nearly 10 ha were marginal (as of the year 2009, State Land Cadastre of Uzbekistan, 2010). Thus, a CDM A/R project could be established through the participation of 30–53 farms, depending on the choice of tree species.

We assumed that the tCER expired after the seventh year. In this case, potential buyers of tCER could use the generated credits to reduce emissions by 235.5 $tCO_2$ with *E. angustifolia*, 369.2 $tCO_2$ with *P. euphratica* and 210.0 $tCO_2$ with *U. pumila*. When estimating a tCER price of 4.76 USD, returns only from tCER were 448 USD for *E. angustifolia*, 702 USD for *P. euphratica* and 399 USD for *U. pumila*, which would be insufficient to cover the initial investments (Table 2).

The largest share of all revenues came from an annual harvest of fruits in *E. angustifolia* stands (5263 USD/ha). The second main income-generating tree product was fuelwood, particularly from the other two tree species that do not bear fruit. For instance, the fuelwood revenue of *P. euphratica* equaled 3389 USD/ha and would be a vital source in covering the entire costs of the CDM A/R project. The highest potential revenues from foliage, observed for *P. euphratica*, did not exceed 258 USD/ha.

For all three tree species, the IRR that considers solely tCER would disfavor such investments. Plantings of *E. angustifolia* were more profitable in the conventional afforestation scheme (65% IRR) than in the CDM A/R scheme (61%) due the annual benefits from fruits that constituted a large share of the total revenues. In contrast, *P. euphratica* and *U. pumila* had higher IRR under the CDM A/R scheme (Table 3).

The NPV estimations that included tCER at the price of 4.76 USD showed that these benefits would be insufficient to cover even the costs related to a CDM project, let alone additional costs for tree plantation establishment and management. Yet, NPV that considers joint revenues of tCER and tree products would render afforestation of marginal croplands financially more attractive than cotton, wheat and, with the exception of *U. pumila*, maize cultivation (Table 4). Thus, for most of the crops cultivated on marginal croplands, the change in land use toward short-rotation tree plantations would bring positive returns under both conventional afforestation and CDM A/R. Only rice was far more profitable, assuming the economically optimal rates of water application over seven consecutive years.

### 3.3. Benefits of CDM A/R in arid areas

Water availability for irrigation is the determinant of agricultural production by farmers because reduced irrigation water supplies would adversely affect crop yields. To determine the tCER prices at which CDM A/R projects would become competitive with the studied crops assuming the crops' economic optimum rates of irrigation water, the tCER credits were differentiated according to levels of water availability (Fig. 3).

At a level of seasonal water availability below 3200 $m^3$/ha, all three tree species were competitive with the studied crops. Above this threshold value, some of the crops would become more profitable than trees, considering the current price of tCER. Raising the tCER price up to 110 USD/tCER would trigger the adoption of CDM A/R projects with *U. pumila*. Afforestation with *P. euphratica* remained competitive with cotton, wheat and maize crops at the current price of tCER, when water supplies did not exceed 12,800 $m^3$/ha. With greater water availability, rice cultivation became more profitable than *P. euphratica* plantations. Due to revenues from fruit production, relatively smaller increases in tCER prices would be needed for afforesting marginal croplands with *E. angustifolia* in lieu of rice cultivation. An increase up to nearly 44 USD/tCER would be needed for *E. angustifolia* if water availability ranges between 16,900 and 26,500 $m^3$/ha, the high amounts of water that are not usually available for marginal croplands in Khorezm.

The difference in total irrigation water use of annual cropping and afforestation over seven years can be considered as water saving. The latter can vary in response to prices of tCER considered (Fig. 4). The present price of 4.76 USD/tCER would allow farmers to get involved in a CDM A/R project while saving between 1600 and 15,300 $m^3$/ha of water each year. As much as 25,000 $m^3$/ha of water annually could be saved by a CDM A/R project with *E. angustifolia* but this would require a substantial increase in the current tCER price (up to 44 USD/tCER).

## 4. Discussion

### 4.1. Estimation of tCER value

CDM A/R are the most common source of forest C credits and account for nearly half of the C market value (ca. 52.2 million USD) of existing forestry projects, i.e., CDM, REDD (Reducing Emissions from Deforestation and Forest Degradation) and IFM (activities implemented to enhance C stocks) (Hamilton et al., 2010). Currently, the C-wood price fluctuates and its determination depends on the agreements made between contract partners such as from developing (seller) and industrialized (buyer) countries. Since the start of the CDM A/R offset mechanism, prices for CER averaged 6.72 USD, with the highest value being 9.85 USD in 2007, and the lowest being 5.89 USD in 2008 (Hamilton et al., 2010). Studies on tCER in Ecuador and Brazil showed that the current price in the market was economically attractive and did not necessitate a significant price increase or any additional income from tree plantations (Guitart and Rodriguez, 2010; Olschewski and Benítez, 2010). In contrast, our findings from a dryland region showed that only small revenues could be expected from tCER alone, and these revenues were insufficient to cover the initial investments and management of a small-scale CDM A/R project. High transaction and establishment costs balanced out the benefits from tCER, as was previously observed in the review of existing CDM A/R projects (Thomas et al., 2010). Based on the case of dryland afforestation in Israel, similar conclusions were derived by Tal and Gordon (2010) who indicated that, under the present prices of CER, the costs of registration and monitoring were likely to prohibit participation in small-scale CDM A/R. The introduction of suitable CDM methodologies, which have increased in number during recent years, could reduce transaction costs for new projects.

Olschewski et al. (2005) advocated the importance of relating the CER value to land productivity, and concluded that the minimum CER supply price would be 0.3 USD for land that was suitable for forestry and 2.5 USD for land with lower suitability. Benítez and Obersteiner (2006) related the C-wood price to the productivity of agricultural land and postulated that profitable tree C projects would be an unlikely

**Table 2**
Discounted cash flow analysis over seven years for the tree species.

| Years | Costs, USD/ha | | | | | | | Revenues, USD/ha | | | | Net returns of CDM A/R, USD/ha |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CDM transaction costs | Machinery | Saplings | Irrigation | Leaching | Labor | Land tax | Fruits | Leaves | Fuelwood | tCER | |
| *E. angustifolia* | | | | | | | | | | | | |
| 0 | 137 | 106 | 312 | 0 | 10 | 209 | 0 | 0 | 0 | 0 | 0 | −773 |
| 1 | 0 | 0 | 0 | 6 | 0 | 367 | 8 | 0 | 0 | 0 | 0 | −381 |
| 2 | 0 | 0 | 0 | 6 | 0 | 322 | 7 | 0 | 0 | 0 | 0 | −334 |
| 3 | 0 | 0 | 0 | 0 | 0 | 143 | 6 | 407 | 0 | 0 | 0 | 258 |
| 4 | 0 | 0 | 0 | 0 | 0 | 113 | 5 | 2267 | 0 | 0 | 0 | 2148 |
| 5 | 0 | 0 | 0 | 0 | 0 | 71 | 5 | 1423 | 0 | 0 | 0 | 1347 |
| 6 | 0 | 0 | 0 | 0 | 0 | 41 | 4 | 828 | 0 | 0 | 0 | 783 |
| 7 | 34 | 0 | 0 | 0 | 0 | 384 | 4 | 339 | 134 | 2248 | 448 | 2747 |
| Total | 170 | 106 | 312 | 12 | 10 | 1651 | 39 | 5263 | 134 | 2248 | 448 | 5794 |
| *P. euphratica* | | | | | | | | | | | | |
| 0 | 214 | 106 | 468 | 0 | 10 | 209 | 0 | 0 | 0 | 0 | 0 | −1006 |
| 1 | 0 | 0 | 0 | 6 | 0 | 367 | 8 | 0 | 0 | 0 | 0 | −381 |
| 2 | 0 | 0 | 0 | 6 | 0 | 322 | 7 | 0 | 0 | 0 | 0 | −334 |
| 3 | 0 | 0 | 0 | 0 | 0 | 123 | 6 | 0 | 0 | 0 | 0 | −129 |
| 4 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | −5 |
| 5 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | −5 |
| 6 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | −4 |
| 7 | 53 | 0 | 0 | 0 | 0 | 534 | 4 | 0 | 258 | 3389 | 702 | 3759 |
| Total | 267 | 106 | 468 | 12 | 10 | 1555 | 39 | 0 | 258 | 3389 | 702 | 1894 |
| *U. pumila* | | | | | | | | | | | | |
| 0 | 122 | 106 | 390 | 0 | 10 | 209 | 0 | 0 | 0 | 0 | 0 | −836 |
| 1 | 0 | 0 | 0 | 6 | 0 | 367 | 8 | 0 | 0 | 0 | 0 | −381 |
| 2 | 0 | 0 | 0 | 6 | 0 | 322 | 7 | 0 | 0 | 0 | 0 | −334 |
| 3 | 0 | 0 | 0 | 0 | 0 | 123 | 6 | 0 | 0 | 0 | 0 | −129 |
| 4 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | −5 |
| 5 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | −5 |
| 6 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | −4 |
| 7 | 30 | 0 | 0 | 0 | 0 | 358 | 4 | 75 | 0 | 2336 | 399 | 2419 |
| Total | 152 | 106 | 390 | 12 | 10 | 1378 | 39 | 75 | 0 | 2336 | 399 | 724 |

Note: Average observed tCER price is 4.76 USD. Real interest rate is 14%.

activity on low productive lands. The forestry study that our assessment is based upon did not cover the variability of tree production in relation to marginality of cropland but demonstrated significant improvement in soil quality, such as increases in topsoil concentrations of organic carbon and macronutrients following the conversion of marginal croplands to tree plantations, particularly those including $N_2$-fixing *E. angustifolia* species (Khamzina et al., 2009b; Hbirkou et al., 2011). Reflecting this environmental value in the price of tCER would increase the attractiveness of CDM A/R in marginal agricultural areas.

Furthermore, when considering CDM A/R in irrigated agricultural settings, the tCER value can be related to irrigation water availability since this is a main factor determining the opportunity cost of tree plantations. In the Khorezm region, agricultural crops use nearly 5 $km^3$ (18,500 $m^3$/ha) annually for irrigation and leaching (Ministry of Agriculture and Water Resources of Uzbekistan, 2010), while the regional water supplies fluctuate within 2.2–5.4 $km^3$ (based on 1992–2010 data of (Ministry of Agriculture and Water Resources of Uzbekistan) (2010)). Within the Khorezm region, farmlands farthest from the river have a low probability of receiving sufficient amounts of water for cropland irrigation (Müller, 2006). The spatial and temporal heterogeneity in water supply pose a risk for the cultivation of rice, which despite being most profitable requires up to 26,500 $m^3$/ha. In a broader context, an expected increase in water demand in the upstream countries could hamper irrigated agricultural production in downstream Uzbekistan, particularly in the lower reaches of the Amu Darya (Martius et al., 2008). Moreover, the climate change is predicted to further decrease the water availability (Perelet, 2007). Thus, forestation of marginal land parcels could be an adaptive land-use option with decreasing water supplies. In turn, the irrigation water "unused" at the afforested marginal plots could become available for fertile croplands (Khamzina et al., 2012). Relating tCER value to the irrigation water supply for marginal croplands could open the scope for increasing water use efficiency through small-scale short-term CDM A/R. This might be implemented by adjusting the irrigation water use to the negotiated tCER price by primarily focusing afforestation activities at locations prone to irrigation water scarcity. The estimated increases in tCER

**Table 3**
Internal Rate of Return under conventional afforestation, tCER and CDM A/R schemes.

| Trees | IRR over 7 years under conventional afforestation | IRR over 7 years under tCER | IRR over 7 years under CDM A/R |
|---|---|---|---|
| | % | % | % |
| *E. angustifolia* | 65 | −10 | 61 |
| *P. euphratica* | 26 | −4 | 28 |
| *U. pumila* | 19 | −12 | 21 |

Note: Average observed tCER price is 4.76 USD.

**Table 4**
Net Present Value of crops and trees over seven years.

| Crops and trees | NPV over 7 years under conventional land use | NPV over 7 years under tCER | NPV over 7 years under CDM A/R |
|---|---|---|---|
| | USD/ha | USD/ha | USD/ha |
| Cotton | −330 | n.e. | n.e. |
| Wheat | −74 | n.e. | n.e. |
| Rice | 8369 | n.e. | n.e. |
| Maize | 1800 | n.e. | n.e. |
| *E. angustifolia* | 5516 | −1221 | 5794 |
| *P. euphratica* | 1459 | −1219 | 1894 |
| *U. pumila* | 477 | −1329 | 724 |

Note: Average observed tCER price is 4.76 USD. Real interest rate is 14%.
n.e. = not eligible under CDM.

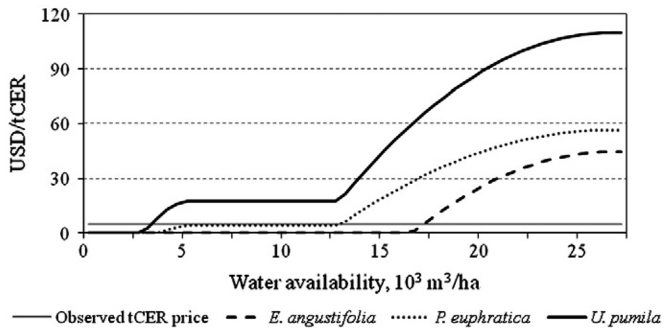


**Fig. 3.** Change in tCER prices depending on irrigation water availability.
Note: Average observed tCER price is 4.76 USD.

price needed to motivate CDM A/R under conditions of adequate water availability do not seem realistic (about 10 times of actual value). However, there may be a possibility to negotiate an environmental premium for irrigation water saving in voluntary markets.

### 4.2. Co-benefits of non-timber products

The production of non-timber goods in drylands gained importance in tree plantation management as demand for them increased considerably. Creedy and Wurzbacher (2001) examined optimal management strategies for the Thomson Water Catchment in Australia. They estimated that the NPV of the catchment was maximized through a high water yield and carbon sequestration as opposed to timber profits alone. In the Mediterranean region, Croitoru (2007) estimated that the annual returns from multiple non-timber products, such as fuelwood, cork, fodder, mushrooms, honey and others, constituted about a fourth of the total value of forests.

Non-timber products were important co-benefits of CDM A/R, as suggested by their dominant share of the total revenues (Table 2). Particularly the IRR estimates emphasized the attractiveness of conventional afforestation with *E. angustifolia* due to annually recurring benefits from the fruits. In addition, energy security can be strengthened via the production of fuelwood at forested plots for meeting the energy demand, currently satisfied through illegal logging of riparian forests and other forest reserves in Uzbekistan (Vildanova, 2006). Tree leaves as a fodder made up a modest share of the total revenues but could be of interest for livestock growers as an inexpensive, protein-rich supplement to basic feeding stuffs (Djumaeva et al., 2009).

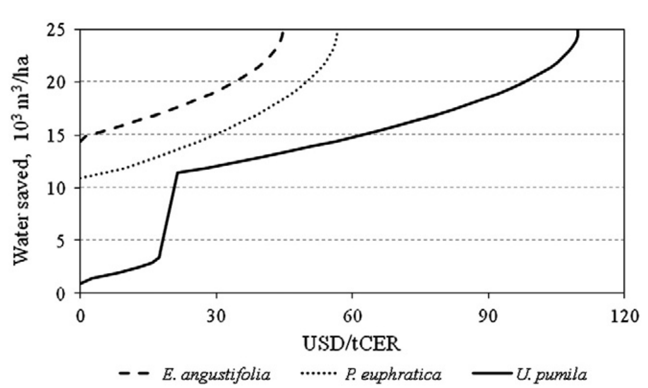


**Fig. 4.** Amount of irrigation water saved by afforestation of degraded croplands with respect to tCER prices.

### 4.3. Local policy implications

Considering the modest value of the tCER per se, local incentives would be essential to fully realize the environmental and financial potential of CDM A/R and their contribution to sustainable development in dryland regions. In particular, the legal support for setting aside marginal cropland parcels for small-scale forestation could lay the foundation for introducing this land use practice. Locally, land tax and income tax exemptions for the initial years of tree plantation establishment are provided as incentives but only for horticultural trees that are not viable on marginal lands (Kan et al., 2008). As shown by the experience of the 28 existing CDM A/R projects (registered until August 2011), local support is needed to cover initial investments and attract farmers to implement a land-use change. In China and India, where most of the CDM A/R projects were registered, these were mostly government or company-initiated, sometimes involving collaboration with international NGOs (Chokkalingam and Vanniarachchy, 2011). In Uzbekistan, the land-based projects have been underrepresented on the country's CDM agenda due to the prevailing skepticism of the cost effectiveness of such projects. The present findings demonstrate the financial competitiveness of CDM A/R on marginal irrigated croplands. When accepting small-scale forestation as a means of improving degraded croplands, rather than as a competitive land use, this option becomes an example for land use optimization in the irrigated dryland regions.

The conducted NPV and IRR analyses considered a constant input use and output level as well as their prices, without accounting for an uncertainty and risks associated with the annual cropping and forestation systems. Future studies should address farmers' risk aversion perceptions, plantation growth scenarios, and future market development to enable uncertainty analyses and further policy advice for CDM forestations in irrigated drylands.

## 5. Conclusions

The IRR and NPV estimates of short-rotation plantations of the three studied tree species endorse a conversion of marginal irrigated croplands, presently cultivated with cotton and wheat, into small-scale areas under the conventional and CDM afforestation. Non-timber products contributed the largest share to the total profits and thus are vital co-benefits of CDM A/R. Although rice was estimated as the most profitable land use on marginal croplands, the high variability in irrigation water supply on the marginal croplands might limit returns from this water demanding crop, requiring further research on risk assessment at farm level.

The estimated revenues from tCER per se would be insufficient to motivate CDM A/R on irrigated marginal croplands, calling for a local support in covering initial investments. Introduction of an environmental premium for irrigation water saving via small-scale forestations could increase attractiveness of such projects. Combining the value of water and land, which are highly interdependent in irrigated drylands, with the value of non-timber products would further enlarge the scope for CDM A/R and enhance its environmental benefits. This research-based assessment lays a foundation for developing a standardized baseline methodology for CDM forestations on irrigated marginal croplands.

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## Appendix

**Table A**
Dry matter of tree products over seven years since planting (kg/ha).

| Years | Tree products | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Leaves | | Fruits | | Stem and twigs | | Coarse roots | |
| | Mean | SEM | Mean | SEM | Mean | SEM | Mean | SEM |
| *E. angustifolia* | | | | | | | | |
| 1 | 1543 | 76 | 0 | 0 | 3045 | 32 | 899 | 46 |
| 2 | 7428 | 343 | 0 | 0 | 30,686 | 269 | 4484 | 225 |
| 3 | 7542 | 587 | 686 | 285 | 59,782 | 785 | 10,797 | 811 |
| 4 | 8457 | 1023 | 4228 | 964 | 64,116 | 1726 | 12,119 | 1403 |
| 5 | 5714 | 710 | 3028 | 1061 | 70,480 | 1290 | 13,736 | 1881 |
| 6 | 6000 | 1269 | 2000 | 831 | 85,710 | 3885 | 25,142 | 6381 |
| 7 | 6285 | 1827 | 914 | 601 | 102,216 | 6481 | 35,304 | 10,881 |
| *P. euphratica* | | | | | | | | |
| 1 | 171 | 21 | n.a | n.a | 318 | 6 | 241 | 26 |
| 2 | 3486 | 517 | n.a | n.a | 9528 | 224 | 3044 | 366 |
| 3 | 6057 | 1052 | n.a | n.a | 25,694 | 761 | 8597 | 1298 |
| 4 | 16,971 | 4728 | n.a | n.a | 79,259 | 3665 | 13,463 | 2304 |
| 5 | 18,342 | 2846 | n.a | n.a | 101,672 | 2581 | 22,351 | 4952 |
| 6 | 19,142 | 4023 | n.a | n.a | 137,136 | 6441 | 34,284 | 8084 |
| 7 | 19,713 | 5200 | n.a | n.a | 170,987 | 10,300 | 48,001 | 11,216 |
| *U. pumila* | | | | | | | | |
| 1 | 654 | 63 | n.a | n.a | 1202 | 22 | 616 | 53 |
| 2 | 2889 | 171 | n.a | n.a | 10,458 | 146 | 4822 | 321 |
| 3 | 3698 | 550 | n.a | n.a | 22,583 | 641 | 10,249 | 1288 |
| 4 | 4054 | 763 | n.a | n.a | 33,283 | 1425 | 17,987 | 3660 |
| 5 | 4707 | 1083 | n.a | n.a | 41,402 | 1220 | 20,873 | 3840 |
| 6 | 4857 | 1066 | n.a | n.a | 59,997 | 2003 | 33,141 | 6164 |
| 7 | 4858 | 1049 | n.a | n.a | 82,611 | 2786 | 45,984 | 8487 |

Note: Only *E. angustifolia* produces fruits.
n.a. = not applicable.
SEM = standard error of the mean.
Source: Khamzina et al. (2008; 2009b).

**Table B**
Descriptive statistics of cropping systems.

| Parameters | Unit | Cotton | | | | Wheat | | | | Rice | | | | Maize | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Min | Max | SD | Mean | Min | Max | SD | Mean | Min | Max | SD | Mean | Min | Max | SD |
| Crop market price | USD/t | n.e. | n.e. | n.e. | n.e. | 227.3 | 204.6 | 364.2 | 75.4 | 681.8 | 545.5 | 909.3 | 53.2 | 227.3 | 181.6 | 363.9 | 67.4 |
| Crop procurement price | USD/t | 227.3 | 144.5 | 272.9 | 36.4 | 107.7 | 82.1 | 158.7 | 16.0 | n.e. | n.e. | n.e. | n.e. | n.e. | n.e. | n.e. | n.e. |
| Crop by-product price | USD/t | 32.4 | 23.3 | 44.8 | 4.4 | 30.4 | 20.9 | 46.1 | 5.3 | 30.1 | 21.4 | 45.7 | 5.3 | 27.4 | 12.2 | 58.4 | 11.8 |
| Seed costs | USD/ha | 16 | 12 | 20 | 2 | 50 | 32 | 71 | 7 | 82 | 55 | 120 | 12 | 80 | 57 | 113 | 10 |
| Labor costs | USD/ha | 152 | 102 | 220 | 43 | 105 | 82 | 120 | 14 | 127 | 85 | 171 | 26 | 81 | 58 | 109 | 16 |
| Fertilizer costs | USD/ha | 152 | 108 | 197 | 32 | 135 | 100 | 163 | 20 | 166 | 120 | 199 | 18 | 150 | 104 | 200 | 23 |
| Machinery costs | USD/ha | 122 | 85 | 166 | 24 | 105 | 69 | 150 | 28 | 650 | 574 | 800 | 45 | 100 | 68 | 131 | 12 |
| Other costs[a] | USD/ha | 50 | 30 | 82 | 12 | 97 | 60 | 145 | 23 | 192 | 118 | 269 | 40 | 27 | 12 | 55 | 8 |

Note: n.e. = not eligible: cotton is not sold on local markets; rice and maize are not part of the state procurement system.
SD = standard deviation.
[a] Costs related to transportation and payments for accessing rural markets.

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